CLAIMS

1. A method for detecting the location of heat sources buried within a sample by using Lock-in Thermography, comprising:

placing the sample on a test system;

applying test signals to the sample at multiple different lock-in frequencies;

while the test signals are applied to the sample, imaging the sample using an infrared sensor;

detecting from the imaging lateral temperature distribution on a surface of the sample;

detecting and analyzing a resulting phase shift between the test signals and a thermal response obtained from the imaging in correlation to thermal heat propagation within the sample;

analyzing the lateral temperature distribution to thereby obtain lateral location of the heat sources; and,

analyzing the phase shift at each heat source position to thereby determine its depth location within the sample.

2. The method of claim 1 further comprising plotting the phase shift at various lock-in frequencies, to thereby obtain phase vs. frequency curve.

3. The method of claim 2, further comprising analyzing the slope of the phase vs. frequency curve to improve the depth location.

4. The method of claim 1, further comprising calculating depth related phase shift to frequency behavior by analytical solution of the thermal wave propagation; and,

correlating the calculated depth related phase shift to frequency behavior to the detected phase shift to indentify the depth of the heat source.

5. The method of claim 1, further comprising:

calculating depth-related phase shift to frequency behavior by finite element modeling of thermal wave propagation;

correlating the calculated depth-related phase shift to frequency behavior to the

detected phase shift to indentify the depth of the heat source.

6. The method of claim 1, further comprises limiting the field of view on the surface of the sample by reading data from only a subset of pixels from the infrared sensor.

7. The method of claim 6, wherein limiting the field of view comprises adding values of neighboring pixels to generate summation data points, and reading only the summation data points.

8. A method for detecting the location of buried heat sources using lock-in-thermography (LIT) system, comprising:

placing a device under test (DUT) on a test system;

applying test signal to the DUT;

while the test signal is applied to the DUT, imaging the DUT using an infrared (IR) camera;

detecting lateral temperature distribution on a surface of the sample to thereby locate the heat-source laterally;

reducing the operational area of the IR camera to obtain a reduced field of view;

subsequently applying electrical excitation signals at multiple different lock-in frequencies to the DUT;

while the test signals are applied to the DUT, imaging the DUT using the reduced field of view;

detecting lateral temperature distribution on a surface of the DUT;

detecting and analyzing a resulting phase shift between the electrical excitation signal and the thermal response in correlation to the thermal heat propagation within the DUT; and,

analyzing the resulting phase shift to thereby obtain depth location of the electrical active heat source.

9. The method of claim 8, further comprising plotting the phase shift at various lock-in frequencies and analyzing the slope of this phase vs. frequency curve in addition to the quantitative phase values to improve z-resolution and measurement reliability.

10. The method of claim 8, calculating depth related phase shift to frequency behavior by analytical solution of the thermal wave propagation; and,

correlating the calculated depth related phase shift frequency behavior to the measured phase shift to indentify the depth of the heat source.

11. The method of claim 8, further comprising calculating depth-related phase shift to frequency behavior by finite element modeling of thermal wave propagation;

correlating the calculated depth-related phase shift frequency behavior to the measured phase shifts to indentify the depth of the heat source.

12. The method of claim 8, wherein reducing the operational area of the IR camera comprises adding values of neighboring pixels to generate summation data points, and reading only the summation data points.

13. The method of claim 8, wherein applying test signal comprises obtaining the test signal from an external source and synchronizing the IR camera to the signal from the external source.

14. The method of claim 8, wherein reducing the operational area of the IR camera comprises using a single pixel IR sensor.

15. A method for time-resolved localization of buried heat sources inside a device under test (DUT) using lock-in-thermography (LIT) system, comprising:

applying test signal to the DUT;

while the test signal is applied to the DUT, imaging the DUT using an infrared camera;

detecting lateral temperature distribution on a surface of the sample to thereby locate the heat-source laterally;

reducing the operational area of the IR camera to obtain a reduced field of view;

subsequently applying electrical excitation signals at multiple different lock-in frequencies to the DUT;

while the excitation signals are applied to the DUT, imaging the DUT using the reduced field of view;

using thermal imaging to detect time-resolved thermal waveforms at the variable lock-in frequency and displaying the time-resolved thermal waveform on a monitor; and,

analyzing the time-resolved thermal waveform to determine the phase shift between the electrical signal and related thermal waveform.

16. The method of claim 15, wherein analyzing the time-resolved thermal waveform comprises using a correlation function.

17. The method of claim 15, wherein limiting the field of view comprises adding values of neighboring pixels to generate summation data points, and reading only the summation data points.

18. The method of claim 15, further comprising using auto-correlation with a sin-function of the same frequency as the lock-in frequency to measure the phase shift of the time-resolved waveform.

19. The method of claim 15, further comprising:

calculating depth related phase shift to frequency behavior by analytical solution of the thermal wave propagation; and,

correlating the calculated depth related phase shift frequency behavior to the measured phase shift to indentify the depth of the heat source.

20. The method of claim 15, further comprising:

calculating depth-related phase shift to frequency behavior by finite element modeling of thermal wave propagation;

correlating the calculated depth-related phase shift frequency behavior to the measured phase shifts to indentify the depth of the heat source.

21. The method of claim 15, further comprising using at least one correlation function to quantitatively analyze the shape of the time-resolved thermal waveform and generating a matrix of resulting correlation factors vs. lock-in frequency.

22. The method of claim 21, wherein using at least one correlation function comprises using at least one of auto-correlation or cross-correlation to predefined waveforms comprising at least one of sine, cosine, square, shark-fin, exponential charging/discharging curve.

23. The method of claim 22, further comprising calculating theoretical correlation factors based on depth-related phase shift to frequency behavior by finite element modeling of thermal wave propagation;

correlating the calculated correlation factors to the measured correlation factors to indentify the depth of the heat source.

24. A system for localizing a defect within an encapsulated device under test (DUT), comprising:

a bench for mounting the encapsulated DUT and connecting the DUT to receive excitation signals from an excitation source;

an infrared camera positioned to obtain IR images of the DUT;

a processor generating a sync signal at frequency f_t and sending the sync signal to the excitation source;

a frequency selector varying the frequency f_t over time;

wherein the processor reads data from the infrared camera and uses thermal imaging of the infrared camera to generate time-resolved thermal waveforms at the variable lock-in frequency and display the time-resolved thermal waveform on a monitor

25. The system of claim 24, wherein the processor further comprises a field of view selector, limiting the field of view of the infrared camera.

26. The system of claim 24, wherein the processor further comprises a field of view selector, enabling read out from only a subset of the pixels of the infrared camera.

CLAIMS

1. A method for detecting the location of heat sources buried within a sample by using Lock-in Thermography, comprising:

placing the sample on a test system;

applying test signals to the sample at a lock-in frequency;

while the test signals are applied to the sample, imaging the sample using an infrared sensor;

detecting from the imaging lateral temperature distribution on a surface of the sample, to thereby spatially localize a hot spot;

reducing the field of view of the infrared sensor to a small area around the center of the hot spot;

increasing the operational speed of the infrared sensor;

imaging the sample using the reduced field of view and increased operational speed of the infrared camera;

calculating plurality of mean values across the reduced field of view in synchronization with the test signal lock-in frequency; and,

analyzing the plurality of mean values to thereby determine depth location of the hot spot within the sample.

2. The method of claim 1 further comprising detecting a resulting phase shift between the test signals and a thermal response of the sample and plotting the phase shift at various lock-in frequencies, to thereby obtain phase vs. frequency curve.

3. The method of claim 2, further comprising analyzing the slope of the phase vs. frequency curve to improve the depth location.

4. The method of claim 2, further comprising calculating depth related phase shift to frequency behavior by analytical solution of the thermal wave propagation; and,

correlating the calculated depth related phase shift to frequency behavior to the detected phase shift to identify the depth of the heat source.

5. The method of claim 2, further comprising:

calculating depth-related phase shift to frequency behavior by finite element modeling of thermal wave propagation;

correlating the calculated depth-related phase shift to frequency behavior to the detected phase shift to identify the depth of the heat source.

6. The method of claim 1, wherein reducing the field of view comprises reading data from only a subset of pixels from the infrared sensor.

7. The method of claim 6, wherein limiting the field of view comprises adding values of neighboring pixels to generate summation data points, and reading only the summation data points.

8. A method for time-resolved localization of buried heat sources inside a device under test (DUT) using lock-in-thermography (LIT) system, comprising:

applying test signal to the DUT at a lock-in frequency;

while the test signal is applied to the DUT, imaging the DUT using an infrared camera;

detecting lateral temperature distribution on a surface of the sample to thereby locate the heat-source laterally;

reducing the operational area of the IR camera to obtain a reduced field of view;

increasing frame rate acquisition of the infrared camera;

subsequently applying electrical excitation signals at multiple different lock-in frequencies to the DUT;

while the excitation signals are applied to the DUT, imaging the DUT using the reduced field of view and in real time calculating average values synchronized to the lock-in frequency;

using the average values to detect time-resolved thermal waveforms at the variable lock-in frequency and displaying the time-resolved thermal waveform on a monitor; and,

analyzing the time-resolved thermal waveform to determine the phase shift between the electrical signal and related thermal waveform.

9. The method of claim 8, wherein analyzing the time-resolved thermal waveform comprises using a correlation function.

10. The method of claim 8, wherein limiting the field of view comprises adding values of neighboring pixels to generate summation data points, and reading only the summation data points.

11. The method of claim 8, further comprising using auto-correlation with a sin-function of the same frequency as the lock-in frequency to measure the phase shift of the time-resolved waveform.

12. The method of claim 8, further comprising:

calculating depth related phase shift to frequency behavior by analytical solution of the thermal wave propagation; and,

correlating the calculated depth related phase shift frequency behavior to the measured phase shift to identify the depth of the heat source.

13. The method of claim 8, further comprising:

calculating depth-related phase shift to frequency behavior by finite element modeling of thermal wave propagation;

correlating the calculated depth-related phase shift frequency behavior to the measured phase shifts to identify the depth of the heat source.

14. The method of claim 8, further comprising using at least one correlation function to quantitatively analyze the shape of the time-resolved thermal waveform and generating a matrix of resulting correlation factors vs. lock-in frequency.

15. The method of claim 14, wherein using at least one correlation function comprises using at least one of auto-correlation or cross-correlation to predefined waveforms comprising at least one of sine, cosine, square, shark-fin, exponential charging/discharging curve.

16. The method of claim 15, further comprising calculating theoretical correlation factors based on depth-related phase shift to frequency behavior by finite element modeling of thermal wave propagation;

correlating the calculated correlation factors to the measured correlation factors to identify the depth of the heat source.